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COMPLETE SPECIFICATION

Improvements in or relating to the Cooling and Insulation of Electrical Apparatus

I, GEORGE RAYMOND SHEPHERD, of 1—3, Regent Street, London, S.W.1, a Subject of the Queen of Great Britain, do hereby declare the invention (communicated by Westinghouse Electric International Company, of 40, Wall Street, New York, 5, State of New York, United States of America, Corporation organised and existing under the Laws of the State of Delaware, in said United States of America), for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to moderately high-voltage generators, or other induction machines, apparatus having one or more windings placed in inductive relation to a magnetizable core. For example, in a dynamo-electric machine, the coil-sides of the high-voltage winding are spaced from both sides of the slots which receive said coil-sides so as to provide a cooling and insulating duct on each side of each coil-side. It is a characteristic feature of this invention that the cooling fluid itself is used as the principal insulating-barrier between the current-carrying conductor and the core. In this way the extra space which is required when a solid insulating layer is used as the principal voltage-withstanding barrier between the conductor and the core is avoided. In this way also a substantially direct heat-transfer from the conductor to the core, through the medium of the fluid within said duct, or both from the conductor and from the core into the cooling and insulating fluid is provided, the fluid being then circulated through a heat-exchanger.

It has been found that the conditions at the junction between a conductor and an insulator have a great effect upon the breakdown-voltage of the insulator and the gas or other fluid which surrounds the insulator. The breakdown-voltage of a good insulator-design, as compared with that of a bad design of the same total dimensions, can be four or more times higher. This invention provides various features making a good insulator-design, as will be subsequently described.

The present invention is particularly designed for equipments in which the cooling and insulating fluid is a gas at a pressure which is considerably higher than atmospheric although it is possible to use insulating oil, or other insulating liquid, for the cooling and insulating fluid.

Although the present invention was particularly designed or primarily intended, for a gas-cooled dynamo-electric machine, such as a turbine-generator of moderately high-voltage rating, it is to be understood, however, that the invention is applicable also to other electrical apparatus having one or more windings placed in inductive relation to a magnetisable core.

With the above objects in view, induction apparatus, according to the present invention, comprises a magnetisable core, at least one winding spaced by insulating barriers from said core so as to provide a duct for a cooling-fluid which is in substantially direct heat transfer relation both with said winding and with said core, said insulating barriers being located between said coil and said core to constitute opposed sides of said duct so that said duct is bounded by an outer surface of said winding, a surface of said core, and the facing surfaces of said insulating barriers, said barriers being formed with intermediate projecting portions extending into said duct in spaced relation to both said coil surface and said core surface.

In order that the invention may be more clearly understood and readily carried into effect, reference will now be made to the accompanying drawing in which:—

Figure 1 is a longitudinal sectional view through the upper left-hand quarter of a

turbine-generator, showing an exemplary form of embodiment of the present invention, the section-plane being approximately as indicated by the line I—I in Fig. 2;

Fig. 2 is an enlarged sectional view, turned sideways, through one of the winding-receiving slots of the stator, as indicated by the section-plane II—II in Fig. 1; and

Fig. 3 is a curve-diagram which will be referred to in the explanation of the invention.

In Fig. 1, there is shown a large polyphase turbine-generator, comprising a stator part 4 and a rotor part 5, enclosed in a gas-tight outer frame-housing 6. The rotor is shown as being mounted on a shaft 7 which extends out through the housing 6 in a gas-tight journal-bearing joint which may be regarded as being symbolically indicated at 8. The housing 6 is filled with a suitable cooling insulating fluid, which is preferably gas in order to reduce the windage-losses. If the cooling and insulating fluid is a gas, its gaseous pressure must be raised and maintained at a value which is considerably higher than atmospheric pressure, in order to provide the necessary breakdown-voltage strength, as will be subsequently described. In cases where windage losses are not a problem, as where the invention is applied to a non-rotating induction machine such as a transformer, or in rotating machines in which the stator member is enclosed in a separate enclosure, separate from the rotor-member, an insulating oil may be used for the cooling and insulating fluid.

A turbine-generator, such as is shown in Fig. 1 commonly has a high-voltage polyphase winding 10 on the stator part 4, while the rotor part 5 carries a field or exciting winding 11, which is always a winding having a relatively low voltage. In some machines, however, the high-voltage winding is on the rotating part, and the low-voltage winding on the stationary part. This invention has particular relation to the high-voltage winding-part of the machine, and while the invention will be particularly described with reference to a machine in which said winding is on the stator part, it is to be understood that the invention is not limited to such an arrangement.

As shown in Figs. 1 and 2, the high-voltage stator-winding 10 has a plurality of multi-conductor coil-sides 12 which are disposed in spaced relation within the winding-receiving slots 13 of the magnetisable stator-core 14.

Each of the coil-sides 12 is made up of a plurality of individual conductors 15, which may either be parallel-connected strands of lightly insulated conductors for the purpose of reducing eddy-currents, or the conductors which make up a coil-side 12 may be the successive turns of a plurality of turns which are bound together to make up a multi-turn coil. The individual copper straps or conductors 15 of each coil-side 12 are each lightly wrapped with a standard low-voltage insulation 16 around each individual conductor, and the entire coil-side 12 is again wrapped around with a standard low-voltage insulation 17, so that each coil-side can be handled as a unit. This outer insulating wrapping 17 is preferably provided with a conducting surface-coating 18 which may be a metal foil or a conducting varnish. It is important, in this invention, to keep most of the voltage between the conducting coat 18 and the iron of the stator-core 14 which surrounds the conductor-receiving slot 13.

The respective coil-sides 12 are held in spaced relation within the slots 13, by means of special channel-shaped members 20 of solid insulating material, overlying respectively the tops and bottoms of the coil-sides 12 in the respective slots 13. These channel-shaped insulating-members 20 have thick side-pieces 21, each of which fits snugly between one of the broad flat outer surfaces of a coil-side 12 and the broad flat core-surface which bounds the corresponding side of the winding-receiving slot 13. These side-pieces 21 thus serve as insulating barriers for spacing the coil-sides 12 from the slots 13. The channel-members 20 are placed only at the tops and bottoms of the coil-sides 12, leaving most of the sides of said coil-sides 12 uncovered, so as to provide ducts 22, each duct being bounded, on one broad flat side, by the conducting surface-coating 18 of a coil-side 12, and on the other broad flat side by the bare surface of the iron which borders the slot 13. The top and bottom edges of each duct 22 are provided by the insulating side-pieces or barriers 21.

It is necessary to provide some means for providing a good insulator-design for the insulating barriers or side-pieces 21 which space the coil-sides 12 from the slots 13. The basic requirements for a good design of insulator are the following:—

(1) The junction between the conductor and the insulator should be placed so that said junction is located in a minimum electrostatic field.

(2) This junction should be placed so that the point of contact is in a concave crack, where there are deionization surfaces.

(3) The potential-gradient along the creepage-surface should be low at this junction.

Fig. 2 (turned sideways) shows the basic design of an improved generator-slot 13, using gas insulation. There is illustrated a design in which two coil-sides 12 lie one over the other, within each slot 13, which is the usual construction. When this is the case, each coil-side must be treated as a separate coil-side, and the two coil-sides in any given slot must be insulated from each other, as by means of the insulating channels 20, which have already been described.

The insulating barriers 21 have intermediate extending portions 24 which extend into the respective ducts 22, in spaced relation to both the coil-side 12 and the core 14. These extending portions provide an increased creepage-length on the insulating barrier, so as to increase the length of surface which is interposed between the surface-coating 18 of the coil-side 12 and the stator-core 14. These intermediate extending portions 24 also provide the concave cracks at the junctions 32 and 34 between the insulating barriers 21 and the coil-side 12 and core 14, respectively. The re-entrant surface-portions adjacent to these concave cracks at the junctions 32 and 34 thus provide deionizing surfaces for deionizing the gas in the immediate vicinity of said junctions. Said re-entrant surfaces also tend to reduce the creepage potential-gradient along the surface of the insulating barrier 21, and this effect is enhanced also by the extra length of creepage-surface which is provided by the extending portions 24 of the barrier.

In most cases it is preferable to use a means for providing a minimum electrostatic field in the vicinity of the aforesaid junctions 32 and 34. A suitable means to this end may consist of imbedded metal foils or other shielding-means 41, which are imbedded within the insulating material of said barriers 21 near each of said junctions 32 and 34. Preferably, each of the shields 41 has a portion which makes contact with the conducting surface against which the barrier lies, at a point spaced back from the junction 32 or 34, as the case may be. Each shield 41 extends out over its junction 32 or 34, as the case may be, thus electrostatically shielding said junction.

Fig. 3 shows the breakdown-voltage curves for a quarter-inch gap and an eighth-inch gap, both in air and in hydrogen, for various pressures, as marked on the diagram. A generator for 13.8 kilovolts, line-to-line, should have about a 0.25 inch total gap at all places where there is a high voltage-gradient in air, and the air should preferbaly be at a pressure of two or more atmospheres. For lower voltages, this gap-spacing can be reduced. A practical voltage-rating for the most advantageous application of this invention is 6.9 kilovolts. It will be understood, however, that the invention is not limited to these particular voltages which have been mentioned.

It will be noted, from Fig. 3, that, whatever gas is used as the cooling and insulating fluid for circulation through the ducts 22, it is practically necessary, in the interests of reducing the gap spacings of the ducts, to use a gaseous pressure which is considerably higher than atmospheric pressure. A reasonably small duct-width, in a circumferential direction is particularly necessary, in order to provide an adequate flux-carrying cross-section of the teeth 43 between the successive slots 13.

From the standpoint of low windage-losses, hydrogen is the preferred coolant, and when hydrogen is the gas which is used, it will be noted from Fig. 3 that the breakdown-voltage curves begin to flatten off after about two atmospheres of pressure, so that a further increase in the gaseous pressure above two atmospheres is of very little benefit.

When air is used as the gaseous medium for providing cooling and insulation, it will be noted that the same gap-spacing will withstand a considerably higher voltage-difference, before breakdown, than in the case of hydrogen at a corresponding pressure; and it will also be noted that breakdown-voltage curves for air do not flatten off so promptly, indicating that pressures considerably higher than two atmospheres will be advantageous from the standpoint of increasing the breakdown-voltage of a given gap-length or circumferential width of the duct 22. It is believed that gases other than hydrogen will in general partake of the nature of air, rather than hydrogen, so far as breakdown voltage-strength is concerned.

A machine designed in accordance with the present invention, and operating with a gas under a considerable pressure higher than the atmospheric pressure, and relying upon that pressure for maintaining its necessary insulation-strength, will obviously be subject to the handicap that the machine will have to be quickly taken out of service if there should be a loss of gaseous pressure, for any reason whatever. Under normal circumstances, a simple pressure-responsive means (not shown) would be installed for instantaneously removing the machine from service and killing its field, upon a loss of gaseous pressure.

Any suitable means may be provided

for circulating the gas (or other fluid) in the ducts 22. As shown in Fig. 1, recirculation of the gas is maintained by means of a fan 45, which is carried by the shaft 7 at each end of the rotor-member 5. A suitable end-baffle 46 is provided at each end of the machine, for leading the recirculated gas into the fan 45, whence the gas is supplied to that end of the stator-windings 10. This gas then enters the ducts 22 and travels longitudinally therethrough to the centre of the machine, at which point a radial ventilating-duct 47 is provided, which causes the gas to flow radially outwardly to a cooler 48, after which the gas is returned to the entrance-side of the fan 45, as indicated by the arrows

A similar cooling-system can be used for the rotor-winding 11, except that, in this case, the voltage of the winding is quite low, and the special insulating channels 20 or barrier-shapes 21 are not needed. The rotor-core 54, in Fig. 1, is provided with conductor-receiving slots 55 which provide simple channels or ducts through which the cooling gas can flow to cool the rotor-winding 11, this gas being expelled from the centre of the rotor, by means of radial openings or vents 56.

What I claim is:—

1. Induction apparatus comprising a magnetisable core, at least one winding spaced by insulating barriers from said core so as to provide a duct for a cooling-fluid which is in substantially direct heat transfer relation both with said winding and with said core, said insulating barriers being located between said coil and said core to constitute opposed sides of said duct so that said duct is bounded by an outer surface of said winding, a surface of said core, and the facing surfaces of said insulating barriers, said barriers being formed with intermediate projecting portions extending into said duct in spaced relation to both said coil surface and said core surface.

2. Apparatus as claimed in Claim 1, wherein the or each said winding comprises a multi-conductor coil, the conductors of which have relatively low conductor-to-conductor insulation.

3. Apparatus as claimed in Claim 2, wherein the or each winding is provided with external insulation and a conductive surface coating on at least the surface or surfaces thereof which face said core.

4. Apparatus as claimed in any of the preceding claims including electrostatic shielding means embedded in said barriers near their junctions with conducting surfaces against which said barriers lie for reducing the electrostatic fields at said junctions.

5. Apparatus as claimed in any of the preceding claims, wherein said winding or each winding is located in slots formed in said core and including channel shaped members of insulating material overlying the tops and bottoms of the or each winding in said slots, the side pieces of said channel shaped members constituting the said insulating barriers.

6. Apparatus as claimed in any of the preceding claims, including a cooling fluid flowing in said duct, said cooling fluid having a high dielectric breakdown strength and constituting the principal insulating barrier between said winding and said core.

7. Apparatus as claimed in Claim 6, wherein said fluid is a gas at a pressure substantially higher than atmospheric.

8. Apparatus as claimed in Claim 6, wherein said cooling fluid is oil.

9. Apparatus as claimed in Claim 6, 7 or 8, including circulating means for causing said fluid to flow through said ducts.

10. Apparatus as claimed in any of the preceding claims, constituting the stator or rotor member of a dynamo-electric machine.

11. Induction apparatus having one or more windings placed in conductive relation to a magnetisable core and having cooling means therefore substantially as hereinbefore described with reference to the accompanying drawings.

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690,537 COMPLETE SPECIFICATION
1 SHEET
This drawing is a reproduction of the Original on a reduced scale.

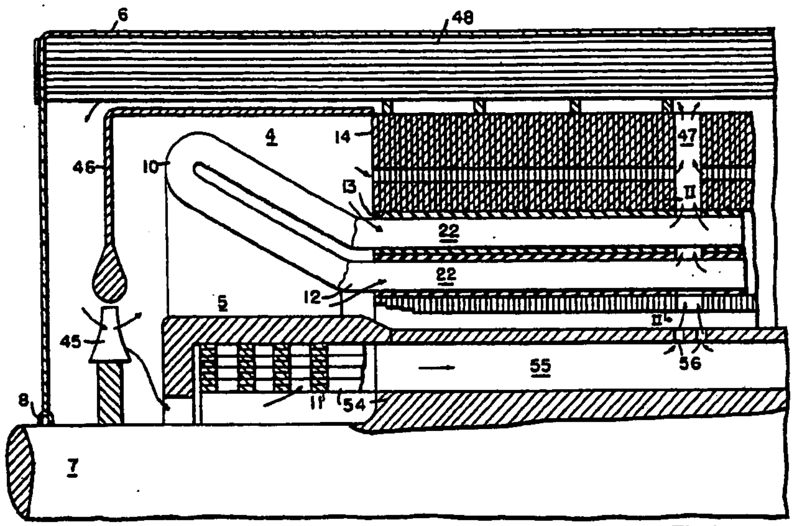

Fig.1.

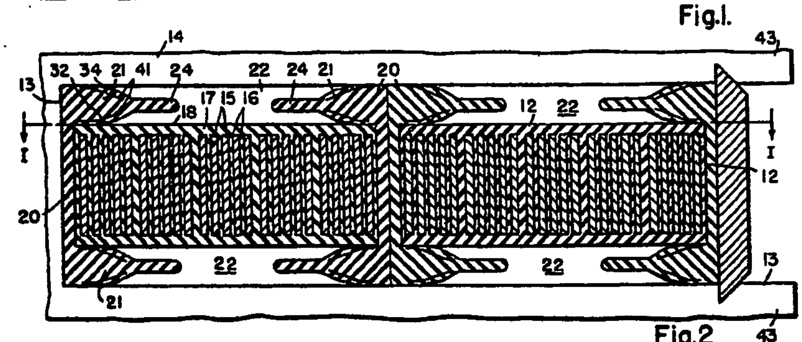

Fig.2.

Fig.3.